Department of Pesticide Regulations
1020 N Street
Sacramento, CA 95814-5624

Pest Management Grants - Applied Research

Pest Management Grants Final Report: Host Animal Resistance in Beef Cattle Fly Control Programs

Contract Number 98-0274

Daniel J. Drake
University of California, Cooperative Extension
Division of Agriculture and Natural Resources
1655 So. Main, Yreka, CA 96097

Prepared for California Department of Pesticide Regulations

Disclaimer

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Department of Pesticide Regulations. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgments

The principal investigator expresses thanks to the staff of the UC Sierra Research and Extension Center for generous and often unknown help with this project. Without their thorough and dedicated efforts, this project would not be possible.

The laboratory work of Dr. Roberto Sainz and his students of the Animal Science Department at the University of California at Davis were invaluable.

Table of Contents

Abstract

Current management practices control horn and face flies of cattle primarily by chemical applications. The ability to select cattle genetically resistant to flies would be of significant value provided the selection techniques were practical and not antagonistic to production. Horn and face flies were counted multiple times on calves, dams, grand dams and great grand dams to permit classification as resistant or susceptible and to evaluate plasma characteristics of those groups. Cattle were successfully categorized using multiple counting dates or means in cluster analysis. Face flies were not closely correlated (0.15 for calves, 0.09 for cows) to horn fly populations. Plasma characteristics measured as optical density at 5 wavelengths were not different between fly susceptibility class or mean fly population levels. This contrasts to other reports. Classification of cattle for fly susceptibility offers potential for genetic selection, however, existing methods field counting over multiple dates, while effective in categorization, is not practical. Further work is needed to characterize plasma characteristics appropriate for different populations of cattle.

Executive Summary

Horn and face flies are economically significant ectoparasites of cattle. Primary control methods are application of chemicals. Cattle with genetic resistance to flies would be valuable provided the resistance was not antagonistic to production traits. Incorporation and adoption of fly resistant cattle requires methods to recognize cattle with genetic resistance in a practical method. In addition, the genetics of resistance must be adaptable to genetic principals such as selective breeding. This project investigated the processes of categorizing cattle fly susceptibility and characteristics of their plasma proteins. Methods employed were similar to those of Tarn et al (1994) who found different plasma protein characteristics of Angus cattle in Arkansas based on their categorization as resistant or susceptible to horn flies.

Cattle were maintained under typical California annual rangeland cattle production conditions at the UC Sierra Research and Extension Center. Predominantly Angus cattle were calved in the fall and weaned in June. Weaned calves were maintained together in a single pasture all summer. Adult females, dams, granddams and great granddams, were maintained together on a separate pasture from their calves.

Horn and face flies were counted approximately every 7 to 10 days from June through August 1999. Horn flies were counted on each side and totaled for individual cattle. Two trained individuals, between 7 am and 12 pm made all counts. Counting was avoided on days with unusual weather conditions such as windy, cloudy or rainy days. Calves were counted 11 times, and adults counted 5 times. Blood samples were obtained at 3 times to relate to traditional animal handling times, at approximately 3 months of age, at weaning, and after the summer fly season, just before sale. Weights were taken at the same times to calculate weight gains, and 205 day adjusted weights.

Large variation between individual cattle for numbers of horn and face flies was observed. Since the cattle were managed together, this suggests a potential for genetic

differences. Variations were also large between counting dates indicating the necessity for counting observations over several different dates before attempting to categorize individual cattle as resistant or susceptible to horn flies. These factors complicate categorization of susceptibility class and limit opportunities for management selection or other management strategies based on multiple counting dates of flies.

Cluster analysis provided a quick and objective method of categorizing cattle into groups with lower and higher fly populations. Either mean horn fly numbers over all counting dates or individual counts for each date provided very similar categorization.

While time consuming to categorize using field counting of flies, categorization of female cattle into resistant or susceptible groups showed that their calves tended ($P=.07$) to be in the same categories. Thus, producers, through much effort, potentially could have some impact on genetic susceptibility. But, this is not a practical method.

The relatively simple process of measuring optical density of plasma proteins to categorize horn fly susceptible as reported in the literature was not successful. Optical density values obtained were within reported values strongly supporting successful laboratory procedures. However, those optical densities were not related to either susceptibility categorization or actual horn fly counts. The inability to relate plasma optical density at five different wavelengths to fly susceptibility precluded further work evaluating genetic relationships between adult females and progeny, and incorporation of that technology into integrated pest management strategies.

Several possibilities may explain the inability to detect plasma differences between cattle of different fly susceptibility. Use of non-purebred cattle may have provided too much diversity to statistically separate means. Cattle populations may be very different in their plasma protein contents and fly susceptibility. Fly populations may not have been large enough to trigger differential protein responses.

Additional optical density measurements at different wavelengths are indicated. In addition, different laboratory procedures, such as gel electrophoresis, may also be of value. The literature suggests these more complicated procedures may be more sensitive than optical density. However, these are additional work. They are also not a practical adoption technique. However, they could lead to increased knowledge that would eventually be adapted to a more practical methodology.

Overall, these data support the potential use of fly counting to categorize cattle into resistant or susceptible groups. There is also some support for a relationship between dams and their progeny to remain in the same susceptibility group. However, more rapid categorization methods such as measuring optical density for categorization do not seem readily applicable at this time.

Summary and Conclusions

This project demonstrates the ability to classify cattle as resistant or susceptible to horn or face flies based on field counts of flies over multiple dates. It did not verify the potential to make similar conclusions based on optical density of plasma proteins. Others (Tarn et al 1994) were able to categorize cattle based on optical densities. Further work is needed to determine appropriate laboratory procedures for these cattle and why these differences occur.

Objectives:

1. Counting flies on individual cattle to classify them as resistant or susceptible to fly infestation.

Introduction:

Obtaining accurate estimates of horn and face flies on the cattle was the first and primary objective. With this information, cattle could be classified and relationships with fly populations and plasma proteins identified. Part of this objective was to classify individual animals as resistant (low fly populations) or susceptible (high fly populations).

Material and Methods:

Cattle and management were used at the University of California Sierra Foothill Research and Extension Center. All practices were conducted in compliance with the UC Animal Care Guidelines. Cows and their fall-born calves were used. From the Centers' cowherd, females with multiple generations of heifer retention were selected for the study. Sufficient numbers of cow and calf pairs were assigned to the study to adequately stock irrigated pasture with the weaned calves.

Cattle were crossbred, predominately Angus and Hereford, but included Red Angus and Shorthorn. Calves were from multiple sire breeding pastures with sires grouped by breed. Calf breed was identified based on the breeding records and color, with black calves recorded as predominately Angus. These would be at least 3/4 Angus. All other calves would be equal or less Angus breeding.

All cow and calf pairs were managed together until weaning in June. Weaned calves were placed on a single irrigated pasture until shipped off the Center for sale. Cows and granddams were placed on non-irrigated pastures.

Weights after overnight withdrawal of feed and water were obtained in February, June (weaning) and September. Weight gains for each interval were calculated. Adjusted 205 day calf weights were calculated (BIF, 1996).

Two workers that were trained together and counted at the same times obtained fly counts of the whole animal. Training efforts included education to yield similar methods and counts between workers. Counts were conducted on days without wind, rain or cloudy conditions. Workers walked among the cattle and mostly used unaided-visual counting. For a limited number of counts, binoculars were used. Separate counts were obtained for horn and face flies. No fly control practices were used. Flies on calves were counted 11 times, June 23, 25, 29, July 6, 14, 19, and August 4, 13, 17, 24, and 30, always between 7 and 11:30 a.m. Flies on cows were counted 5 times, June 22, 28, July 6, 19, 26 and August 5, and granddams 7 times, July 14, 19, 26, 30, and August 4, 13, and 16, between 7:30 a.m. and 1:30 p.m.

Statistical Analysis

Fly counts were not normally distributed and were transformed by square root. Cattle were classified susceptible or resistant to flies by K-means cluster analysis of fly counts thereby maximizing between-cluster variation relative to within-cluster variation. All statistical procedures were performed with Systat (Version 9).

Results and Discussion

Fly Counts

Calves

Calf horn fly, *Haematobia irritans* (L.), numbers tended to increase during the summer but showed large variation from date to date, and among cattle (Table 1). Mean values for counting dates ranged from 59±29 to 390±195 horn flies per calf. The correlation between left side and right side of cattle counts was .586 (n=627). The correlation between left (.888) and right (.893) side counts to combined whole body counts was high.

Horn fly numbers were not closely (.152) correlated to face fly numbers for all counts combined (n=657). For individual counting dates, correlations ranged from .0002 to .45. Individual animal face fly numbers were related to horn fly number by the regression

face flies=3.8601+0.0046*horn fly number SE 4.32 R^2=.02
(P=.0001)

Non-normal distribution of horn fly counts for each date was observed (Figure 1). Square root transformations produced normal distributions (Figure 2). Overall mean horn (P=.30) and face (P=.42) flies were similar between steers (178±9.4, 4.79±.22) and heifers (165±8.0, 4.55±.19), respectively.

Mean face fly, *Musca autumnalis* DeGeer, numbers on calves for each counting date ranged from 0.4±0.8 to 8.8±5.8 (Table 2). The maximum number of face flies observed on a calf was 31. Non-normal distribution of face fly counts for each date were observed (Figure 3). Square root transformations produced normal distributions (Figure 4).

Cows.

Mean horn flies on cows for each counting date ranged from 67.1±35.0 to 138.2±64.6 (Table 3) and for face flies from 1.3±1.6 to 10.9±6.3 (Table 4). The correlation between sides for horn flies was .354, with the left side (.832) or right side (.813) highly correlated to total horn fly counts. Transformations of horn fly counts for cows showed normal distribution (Figure 5).

Face fly numbers were not well-correlated (.090) to horn flies for all counts combined (n=285). For individual counting dates, correlations ranged from 0.046 to 0.24. Individual animal face fly numbers were related to horn fly number by the regression

face flies=3.828+0.0071*horn fly number SE 4.85 R^2=.0081
(P=.13)

Brown et al (1994) found a significant correlation of 0.23 between cow horn and face fly numbers.

Grand and great grand dams.

Horn fly counts on grand and great grand dams were higher than on cows ranging from 240 ±154 to 333 ± 129 for counting dates (Table 5). Face fly numbers on grand dams were similar to numbers on cows (Table 6). The correlation between sides for horn flies was .219, with the left side (.759) or right side (.802) highly correlated to total horn fly counts. Square root transformations produced normal distribution histograms (Figures 6 and 7).

Face fly numbers were not well-correlated (.167) to horn flies for all counts combined (n=273). For individual counting dates, correlations ranged from 0.17 to 0.42. Individual animal face fly numbers were related to horn fly number by the regression

face flies=3.136+0.0079*horn fly number SE 6.23 R^2=.03
(P=.0057)

Classification of Host Resistance

Calves

Classification of calves into horn fly resistant or susceptible categories using cluster analysis of transformed whole body horn fly counts resulted in good separation (Figures 8). Classification was also conducted using mean (Figure 9) and transformed mean (Figure 10) horn fly counts instead of the individual counts. Results from these two methods were all calves except 3 being assigned to the same category as when using transformed individual counting date data. The horn fly counts for these three calves were borderline between resistant and susceptible. This suggests transformed individual date counts, mean or transformed mean of all counting dates are suitable for separation into resistant or susceptible categories.

Using classification by transformed mean horn fly counts, overall mean horn fly counts for susceptible calves were 216 ± 25 compared to 136 ± 22 for resistant calves (P<.0001). There was no sex by category interaction (P=.24). Horn fly counts for these resistant and susceptible classifications (Figure 11) were also different (P<.02) for each counting date except July 6. Horn fly counts on July 6 appear to have fewer cattle with higher numbers of flies, although the mean was similar to other dates. Histogram distribution (Figure 12) using transformed mean horn fly counts shows good separation of individuals into resistant or susceptible categories.

In contrast, square root transformed face fly counts for individual counting dates for face flies did not result in good separation of categories (Figure 13). Use of non-transformed face fly counts (data not shown) was similar to transformed analysis. With mean values (Figure 15) or transformed mean values (Figure 14) improved separation was observed. Classification by transformed mean face fly count resulted in overall mean face fly count for resistant calves of 1.24 SE 0.06 and for susceptible calves of 1.89 SE 0.09 (P<.0001). There was no sex by category interaction (P=.33). Six of the eleven counting dates were signficantly different (P<.05) for resistant and susceptible calves using the transformed mean face fly values for separation.

Cows

Cows were classified into categories of resistant or susceptible to horn or face flies by the same four processes as calves. For horn flies, separation into categories was effective using: 1.) individual counting dates for horn flies (Figure 16), 2.) transformed by square root data from 1 (Figure 17), 3.) mean values (Figure 18) and 4.) square root transformed mean values (Figure 19). Visually the mean values produced the best separation.

Categorization patterns for face flies (Figures 20, 21, 22 and 23) were similar to those for horn flies.

Grand and Great grand dams

Grand and Great grand dams were classified for horn (Figures 24, 25, 26 and 27) and face (Figures 28, 29, 30 and 31) flies by the same methods. For these individuals, mean values provided visually better separation into resistant and susceptible categories.

Summary of Classification

Visual evaluation of figures (Figures 8-31) for separation of individuals and comparison of calculated data and variation (Table 7) suggest cluster analysis using either means or square root transformed means of horn or face fly counts provided the best separation, greatest difference between means and smallest variation within categories. Transformed means were perhaps slightly superior.

These methods of susceptibility classification offer greater application than Tarn et al (1994) who used data from 3 years of fly counting of cows.

Weight Gain

Weights for calculation of gain were obtained in February, at weaning on June 18 just before the first fly count and on August 18. Gain evaluation was restricted to calves (n=37) of Angus sires for greater uniformity. Gain for each of these periods, the overall gain and adjusted 205d weight gains are shown by fly susceptibility classification for calves and dams (Table 8). All gains were similar for calf classification categories. Horn fly counts on these calves during June and July were generally between 50 and 100 horn flies per calf, and about 200 during August. The overall mean calf horn fly count was 170±49, means for resistant-categorized calves were 131±23 compared to susceptible-categorized calves 216±26 horn flies per calf ($P<.0001$). Mean horn fly count when regressed on gain from June to August was not ($P=.17$) related to gain. At the levels of fly infestation on weaned calves reported here, no deleterious impacts on weight gain were found. It is noted that perhaps the levels of infestation on the susceptible calves was not great enough to depress gain. Drummond (1987) reported by Byford et al (1992) re-analyzed reported ectoparasite infestations on gain. He found a 13.6 percent reduction in gain of stocker cattle with horn flies, but infestations levels were 440 flies per animal, much higher than our levels. To further evaluate fly numbers on gain, regression analysis was restricted to either calves with mean horn fly levels below 170 or above 170. Calves with fewer than 170 ($P>.34$), or greater than 170 flies ($P=.68$) did not have signficant regression coefficients to gain. The restriction limited total observations (n=19), perhaps severely reducing the power of the test.

Dam fly counts were not obtained during the suckling phase of calf growth. However, dams were classified for fly susceptibility during the weaned phase of production. Based on those categorizations, dam fly susceptibility did not affect 205d weights ($P=.15$, Table 8). Campbell, 1976; Kunz et al, 1984; Quisenberry and Strohbehn, 1984; Cocke et al, 1989 found weaning weights variable when compared to different levels of horn flies. No economic weight gain between insecticide treated cows and calf weaning weight was found by Schreiber et al, 1987; Brethour et al , 1987; Haufe and Thompson, 1964 and Haufe , 1973.

Calf and Dam Host Classification

Dams that were resistant tended to have resistant calves. Of 23 dams classified as resistant to horn flies, 13 of their calves were also resistant, but 10 were susceptible, P=.07 (Table 9). For dams susceptible to horn flies (n=14), 7 calves were classified as resistant and 7 susceptible. A similar pattern was found for face flies (P=.58).

Summary and Conclusions

Large variation between individual cattle for numbers of horn and face flies was found. Variations were also large between counting dates indicating the necessity for observations over several different dates before attempting to categorize cattle as resistant or susceptible to horn or face flies. Cluster analysis was a satisfactory method to objectively classify cattle as resistant or susceptible using either multiple counting dates or the mean from multiple counting dates.

Despite differences in fly populations among calves, differences in weight gain were not observed. This may have been due to relatively low numbers of flies.

2. Obtaining blood samples at multiple times typical of usual production practices for use in laboratory tests to measure plasma protein markers as indicators of resistance or susceptibility of cattle to horn and face flies.

Introduction

Evaluation of plasma proteins at different times and thus ages of cattle would be advantageous. Early identification is important due to potential alternate management for cattle being retained for breeding purposes versus those destined for finishing and processing into beef. It would be most practical to know plasma characteristics at specific times during the production cycle that would be most conducive to collection of samples.

Materials and Methods

Blood samples were obtained from individually identified adult female cattle and their calves at three times. Samples were obtained by jugular veni-puncture with sterile equipment. All samples were cooled, centrifuged and plasma removed within 24 hours of collection. Plasma was stored at -20 degrees or less at UC Davis.

Results and Discussion

Blood samples were obtained in February, at weaning and just before shipment at sale time in August. Samples were collected during the weighing process on an individual animal scale.

Summary and Conclusion

This process provided convenient time for sampling, and no problems were encountered.

3. Compare actual field classification to laboratory tests for efficacy of protein markers at specific ages.

Introduction:

Plasma protein characteristics of horn fly resistant and susceptible cattle were determined for optical density at five wavelengths. These characteristics were compared for sub-groups identified as resistant or susceptible to horn flies. A strong relationship would offer potential for identification and selection of resistant cattle through plasma optical density.

Materials and Methods

Plasma samples were stored at -20 degrees F until time of assay. Plasma proteins reacted in typical and expected manners indicating satisfactory storage. Absorbency assays followed the procedures of Tarn et. al (1994). Absorbency, recorded as optical density, was measured at wavelengths of 405, 450, 492, 550 and 620. All measurements were conducted with plasma adjusted to equal protein concentrations. Final measurements were run with control samples as checks and in triplicate. Simple means were used for statistical analysis. ANOVA was used to test absorbency differences between resistant and susceptible categorized cattle. Regression was used for weight gain and optical density relationships.

Results and Discussion

Cattle categorized as resistant or susceptible had similar optical densities (Table 10) at each of the wavelengths measured. This is in contrast to Tarn et al (1994) findings of differences at 200 and 464 nm. Those workers found breed differences in absorbance. Our cattle (n=66) were of mixed breed types. Selecting a subset of calves (n=37) that were predominately black in color representing predominately Angus breeding gave similar results of no significant differences.

The number of horn flies was also not closely related to the absorbance of plasma proteins. Graphs (Figure 32) and regression (not shown) indicated no significant linear relationships between mean horn flies per calf (from 11 counting dates) to optical density at five wavelengths.

Calf average daily gain (ADG) during the summer fly season (June to August weight period) was related to absorbance at 620 nm. Increasing optical density in plasma was positively related to ADG during this period for both the complete group of calves (P=.001, n=66) and for the more breed selective group (P=.02, n=37). While we did not find increased optical density related to fly numbers or cattle susceptibility, those cattle classified as susceptible did have numerically greater optical density. Tarn et al (1994) found susceptible cattle had significantly higher optical density at 464 and 200 nm.

ADG from June to August was also positively related to optical density at 550 (P=.05), 492 (P=.03) and 450 (P=.06) nm, but not to 405 nm (P=.17).

In contrast, 205d weights were negatively related to optical density. 205d weights declined with increasing optical density at 405 (P=.11), 450 (P=.07), 492 (P=.08), 550 (P=.10) and 620 (P=.02) nm.

A similar pattern was found when calves were grouped by cluster analysis into high and low optical density groups. Calves classified as high optical density had higher (1.1 vs. 1.5 lbs./day, P=.07) ADG from June to August, however 205d weights were similar (310 vs. 325 lbs., P=.43).

It is unclear why higher optical densities were related to improved ADG. This is in contrast to Tarn et al (1994).

Summary and Conclusions

A relatively simple optical density measurement of plasma proteins did not repeat previous work (Tarn et al, 1994) relating increased optical density to horn fly susceptible cattle. Furthermore, optical density of plasma proteins was not related by regression to mean horn fly populations on calves.

Increasing optical density was positively related to increased gain during the summer period. With the experimental cattle, this may not be surprising since optical density did not relate to horn fly populations. However, based on Tarn et al (1994) increased density were suggested as indicative of horn fly susceptibility and increased horn fly populations. These increased fly populations would be expected to result in reduced weight gains. Tarn et al (1994) did not measure weight gains.

Further work with techniques that may be less sensitive to breed differences and more specific to fly susceptibility would be worthwhile. These techniques are more difficult to conduct, potentially hampering adoption but perhaps worthwhile to better understand mechanisms controlling fly susceptibility of cattle.

4. Evaluate relationships between maternal and offspring plasma markers indicating horn and face fly resistance level.

Introduction

This objective required measuring plasma markers associated with fly susceptibility in dams and their progeny. The goal being to understanding those relationships and possibly some of the heritance of fly susceptibility.

Material and Methods

Plasma samples from calves, their dams, grand dams and great grand dams were obtained as above. Each individual in these classes of cattle were categorized as resistant or susceptible to horn flies.

Results and Discussion

We were unable to detect differences in optical density (a measure of plasma proteins) at five wavelengths between cattle classified as resistant or susceptible. Therefore, it was not possible to evaluate relationships between calves and their dams.

Summary and Conclusions

Due to the inability to link or relate plasma protein by optical density to categorized susceptibility, additional relationships between calves, dams and granddams is not possible.

5. Develop fly control programs that incorporate host animal resistance.

Introduction

With the information generated from objectives 1 through 4 a strategy program for controlling horn and face flies on cattle is desired. This new information would target the identification and selection opportunities for increasing the number of cattle that are gentically resistant to horn and face flies.

Materials and Methods

Programs utilized information generated from objectives 1 through 4 above.

Results and Discussion

Integrated Horn and Face Fly Control Strategies

These results demonstrate large variation between individual cattle for numbers of horn and face flies. Since the cattle were managed together, this suggests a potential for genetic differences. Variations were also large between counting dates indicating the necessity for observations over several different dates before attempting to categorize individual cattle as resistant or susceptible to horn flies. These factors complicate categorization of susceptibility class and opportunities for management selection or other management strategies.

When horn or face fly populations are determined on multiple counting dates, cluster analysis provides a quick and objective method of categorizing cattle into groups with lower and higher fly populations. Either mean horn fly numbers over all dates or individual counts for each date provide very similar categorization.

While time consuming to categorize, categorization of female cattle into resistant or susceptible groups showed that their calves tended (P=.07) to be in the same categories.

Thus, producers, through much effort, potentially could have some impact on genetic susceptibility. But, this is not a practical method.

The numbers of horn flies on weaned calves under these conditions was apparently insufficient to hinder weight gain. During the period of June to August, mean horn fly numbers were 170 per calf. The literature suggests much higher levels, possibly up to 400, to elicit reductions in weight gain. Establishment of threshold values was not in the objectives of this trial, but data suggests horn fly levels above 170 are needed before reductions in weight gain.

The relatively simple process of measuring optical density of plasma proteins to categorize horn fly susceptible as reported in the literature was not successful. Values obtained were within reported values strongly supporting successful laboratory procedures. However, those optical densities were not related to either susceptibility categorization or actual horn fly counts.

Several possibilities may explain those results. Use of non-purebred cattle may have provided too much diversity to statistically separate means. Cattle populations may be very different in their plasma protein contents and fly susceptibility. Fly populations may not have been large enough to trigger differential protein responses.

Due to the inability to link or relate plasma protein by optical density to categorized susceptibility, additional relationships between calves, dams and granddams is not possible.

Additional optical density measurements at different wavelengths are indicated. In addition, different laboratory procedures may also be of value. However, these are additional work. They also start to become more of a research methodology rather than a Pest Management Strategy.

Overall, these data support the potential use of fly counting to categorize cattle into resistant or susceptible groups. There is also some support for a relationship between dams and their progeny to remain in the same susceptibility group. However, more rapid categorization methods such as measuring optical density for categorization do not seem readily applicable at this time.

Summary and Conclusions

This project demonstrates the ability to classify cattle as resistant or susceptible to horn or face flies based on field counts of flies over multiple dates. It did not verify the potential to make similar conclusions based on optical density of plasma proteins. Others (Tarn et al 1994) were able to categorize cattle based on optical densities. Further work is needed to determine appropriate laboratory procedures for these cattle and why these differences occur.

References

Beef Improvement Federation. 1996. Guidelines for uniform beef improvement programs. 7th Edition. Curtiss Bailey, Editor. Northwest Research Extension Center, 105 Experiment Farm Road, Colby, KS 67701.

Brethour, J.R., T.L. Harvey, R. Negus, L. Corah and D. Patterson. 1987. Effect of cattle breed and flucythrinate-impregnated eartags on horn fly (Diptera: Muscidae) control on yearling heifers. J. Econ. Entomol. 80:1035-1038.

Brown, A.H., Z.B. Johnson, R.B. Simpson, M.A. Brown, C.D. Steelman and C.F. Rosenkrans, Jr. 1994. Relationship of horn fly to face fly infestation in beef cattle. J. Anim Sci 72:2264-2269.

Byford, R.L., M.E. Craig and B.L. Crosby. 1992. A review of ectoparasites and their effect on cattle production. J Anim Sci 70:597-602.

Campbell, J.B. 1976. Effect of horn fly control on cows as expressed by increased weaning weights of calves. J. Econ. Entomol. 69:711-712.

Cocke, J., Jr., R. Knutson and D.K. Lunt. 1989. Effects of horn fly control with cyhalothrin ear tags on weight gains in weaning calves in Texas. Soutwest. Entomol. 14:357-362.

Drummond, R.O. 1987. Economic aspects of ectoparasites of cattle in Nor America. In: W.H.D. Leaning and J. Guerrero (Ed.) The Economic Impact of Parasitism in Cattle. Proc. MSD-AGVET Symp. XXIII World Vet. Congress, August 19, 1987, Montreal, PQ, Canada.

Haufe, W.O. 1973. Interaction of pesticidal toxicity, parasites, and reversible anticholinesterase activity as stresses on growth rate in cattle infested with horn flies Haemotobia irritans (L.). Toxicol. App. Pharmocol. 25:130-144.

Haufe, W.O. and C.O.M. Thompson. 1964. Weight changes on dry rante in relation to chemical treatments for fly control. Can J. An. Sci. 4:272-280.

Kunz, S.E., J.A. Miller, P.L. Sims and D.C. Meyerhoeffer. 1984. Economics of controlling horn flies (Diptera: Muscidae) in range cattle management. J. Econ. Entomol. 77:657-660.

Quisenberry, S.S. and D.R. Strohbehn. 1984. Horn fly (Diptera: Muscadae) control on beef cows with permethrin--impregnated eartags and effect on subsequent calf weight gains. J. Econ. Entomol. 77:422-424.

Schreiber, E.T., J.B. Cambell, S.E. Kunz, D.C. Clanton and D.B. Hudson. 1987. Effects of horn fly (Diptera: Muscidae) control on cows and gastrointestinal worm (Nematode: Trichostrongylidae) treatment for calves on cow and calf weight gains. J. Econ. Entomol. 80: 4451-454.

Tarn, C.Y., C.F. Rosenkrans, Jr., C.D. Steelman, A.H. Brown, Jr. and Z.B. Johnson. 1994. Plasma characteristics of beef cattle classified as resistant or susceptible to horn flies. J Anim Sci 72:886-890.

Glossary of Terms, Abbreviations and Symbols

All terms, abbreviations and symbols used in this document are described at their first usage.

Figures

Figure 1. Histogram distributions of horn flies (X axis) for calves for each counting date.

Date 1 = June 23, Date 2=June 25, Date 3=June 29, Date 4=July 6, Date 5=July 14, Date 6=July 19, Date 7=August 4, Date 8=August 13, Date 9=August 17, Date 10=August 24, and Date 11=August 30.

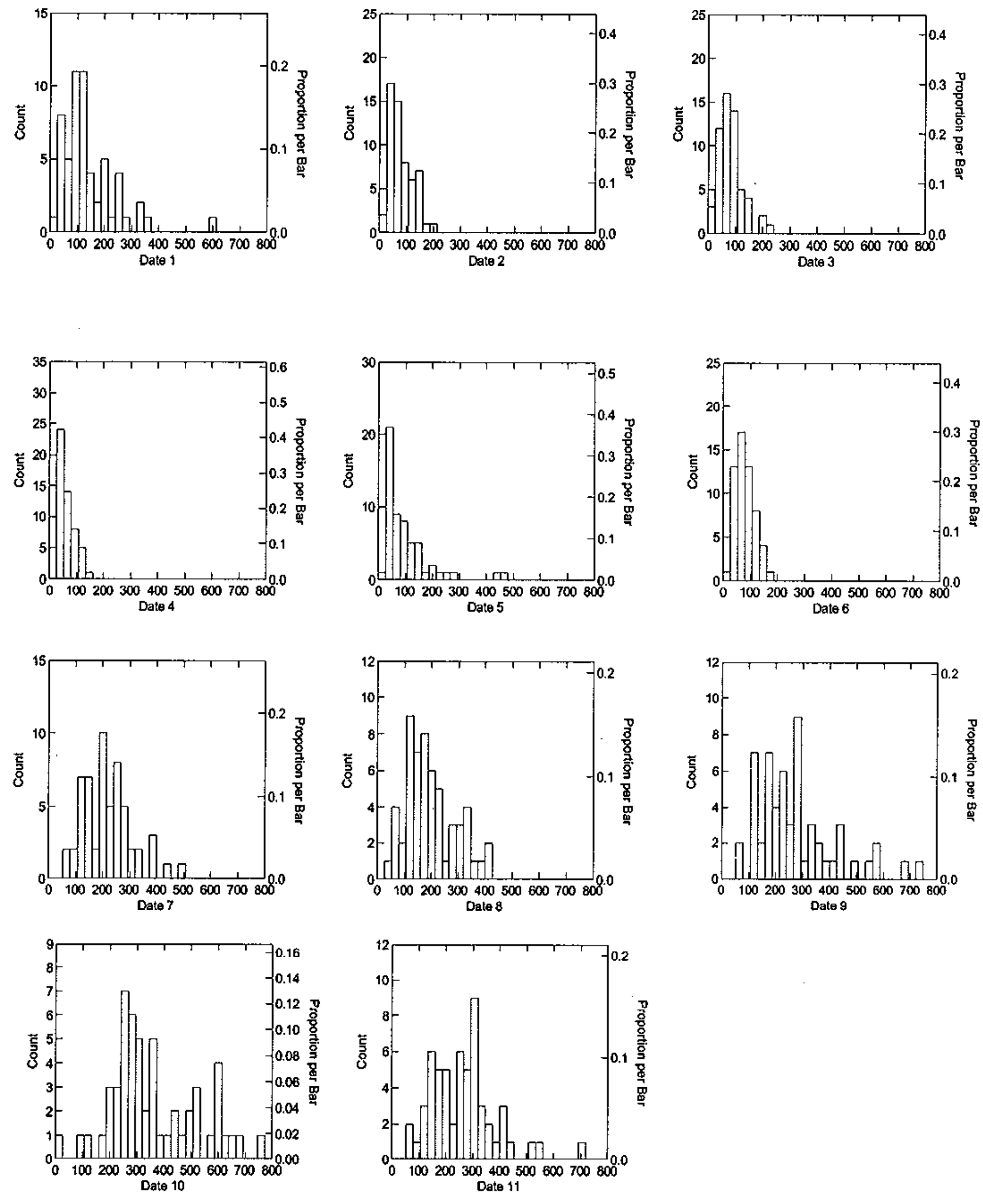


Figure 2. Histogram distributions of square root transformations of horn flies (X axis) on calves for each counting date.

Date 1 = June 23, Date 2=June 25, Date 3=June 29, Date 4=July 6, Date 5=July 14, Date 6=July 19, Date 7=August 4, Date 8=August 13, Date 9=August 17, Date 10=August 24, and Date 11=August 30.

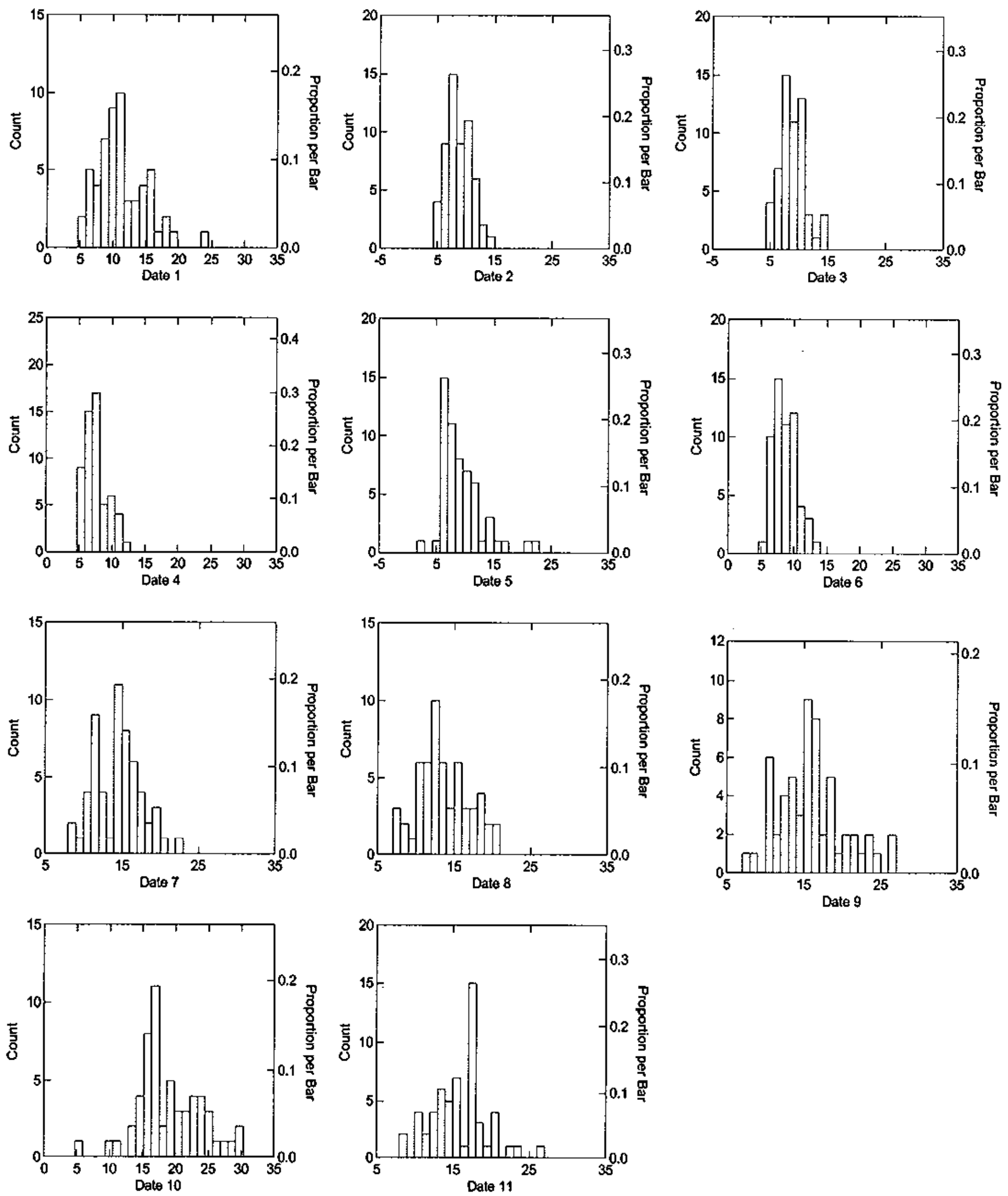


Figure 3. Histogram distributions of face flies (X axis) for calves for each counting date.

Date 1 = June 23, Date 2=June 25, Date 3=June 29, Date 4=July 6, Date 5=July 14, Date 6=July 19, Date 7=August 4, Date 8=August 13, Date 9=August 17, Date 10=August 24, and Date 11=August 30.

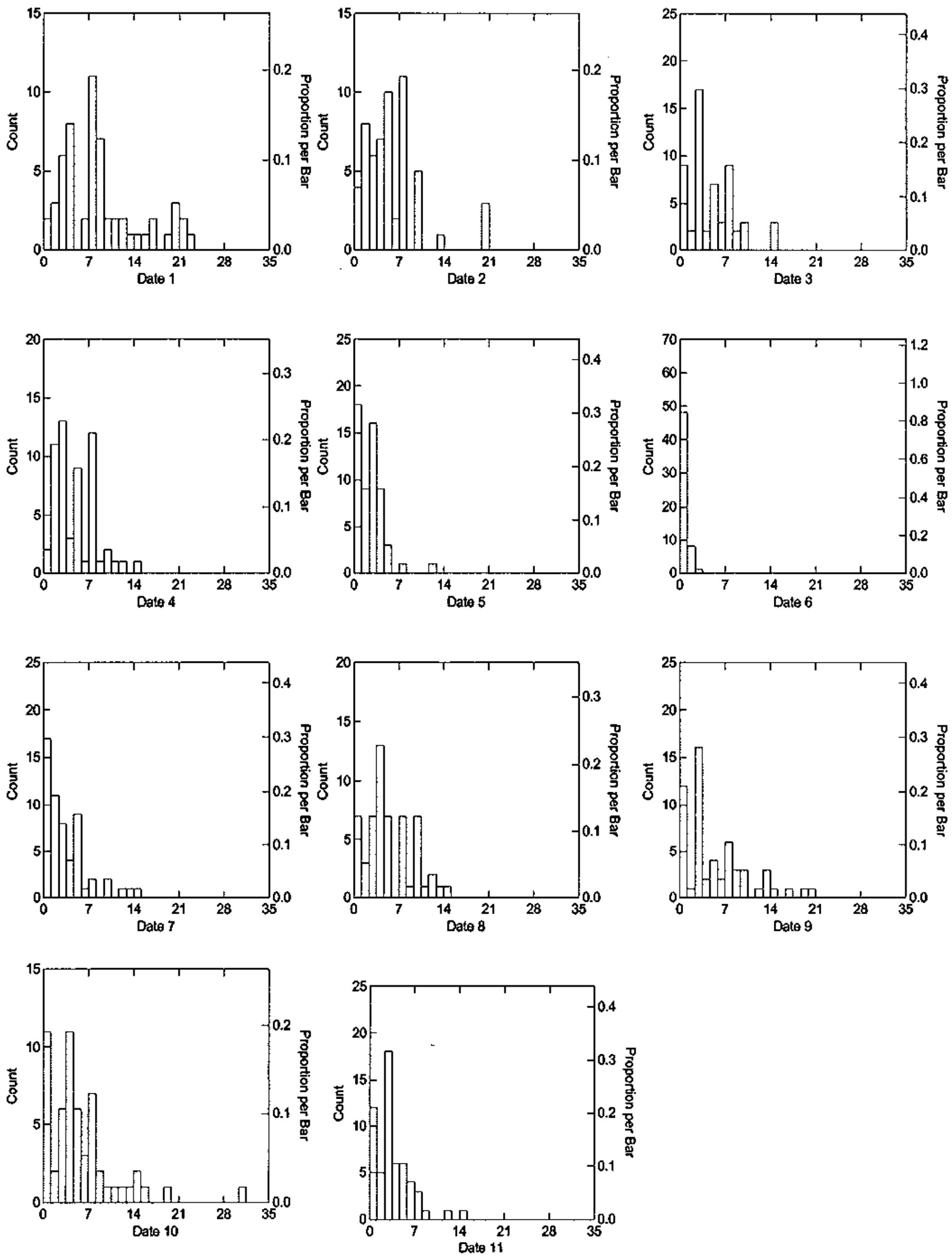


Figure 4. Histogram distributions of square root transformations of face flies (X axis) for calves for each counting date.

Date 1 = June 23, Date 2=June 25, Date 3=June 29, Date 4=July 6, Date 5=July 14, Date 6=July19, Date 7=August 4, Date 8=August 13, Date 9=August 17, Date 10=August 24, and Date 11=August 30.

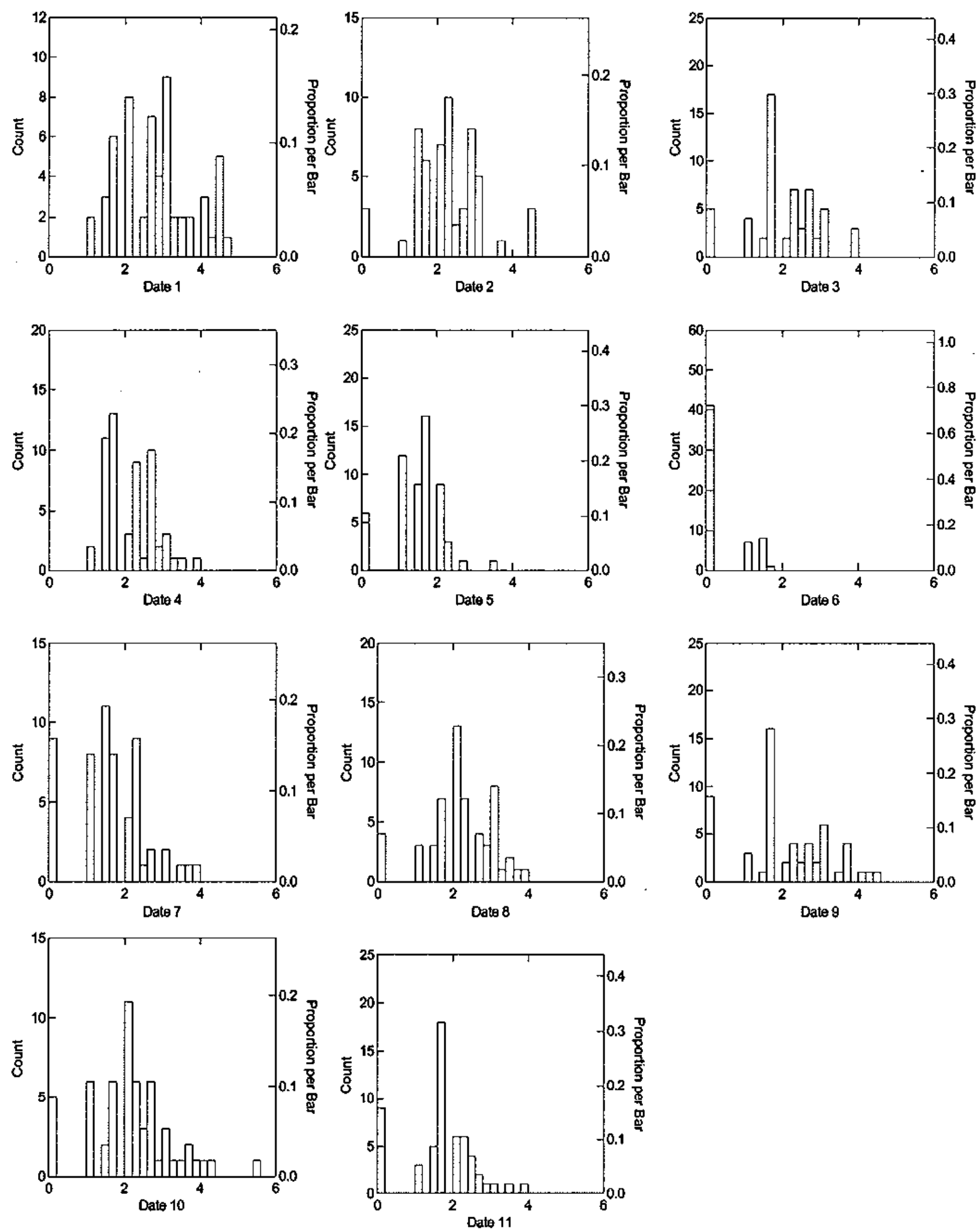


Figure 5. Square root transformed horn fly counts (X axis) of cows for each counting date.

Date 2=June 28, Date 3=July 6, Date 4=July 19, Date 5=July 26, Date 6=August 5.

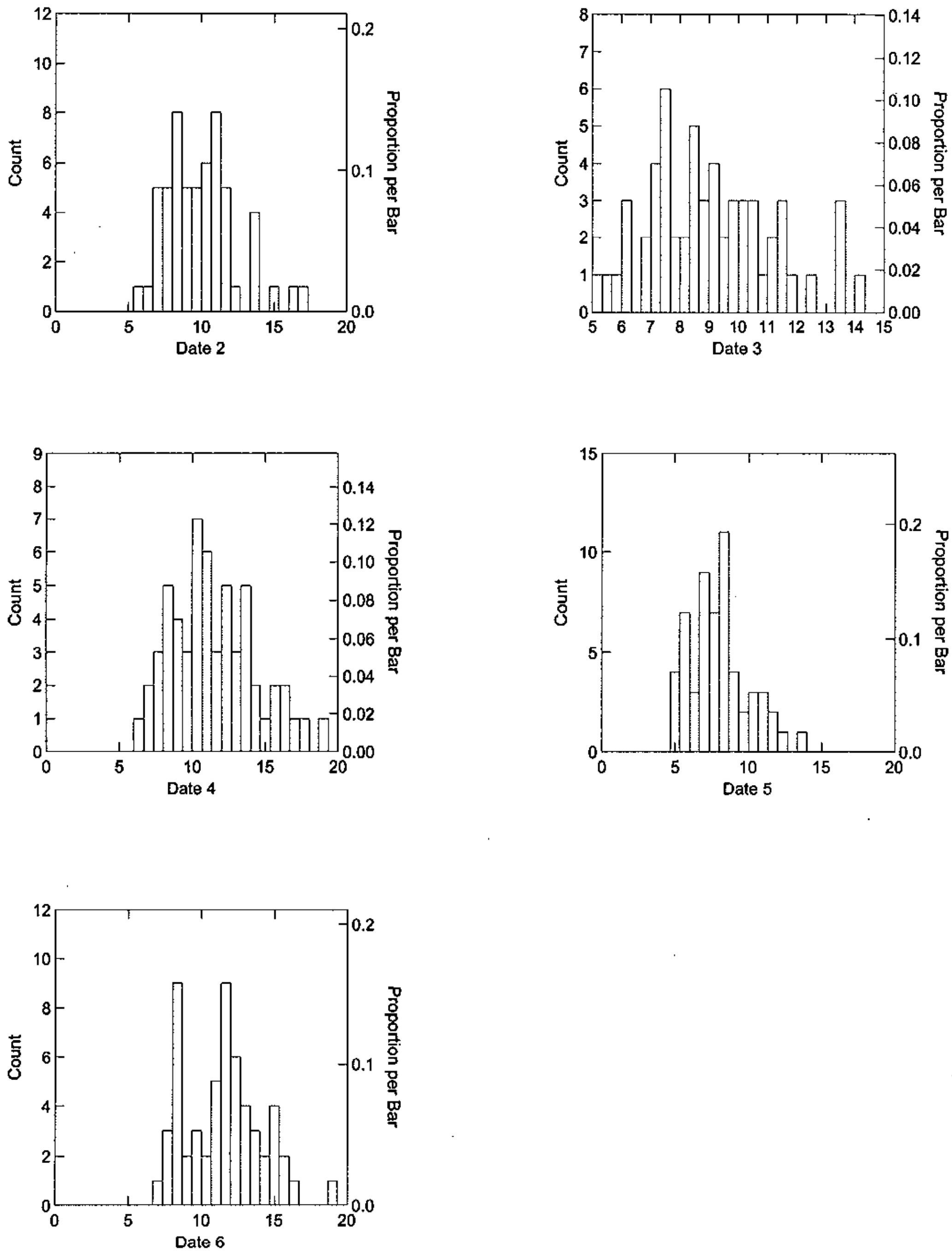


Figure 6. Square root transformed horn fly counts (X axis) of grand and great granddams for each counting date.

(Graph order: Left to right, top to bottom: July 14, July 19, July 26, July 30, August 4, August 13, and August 16).

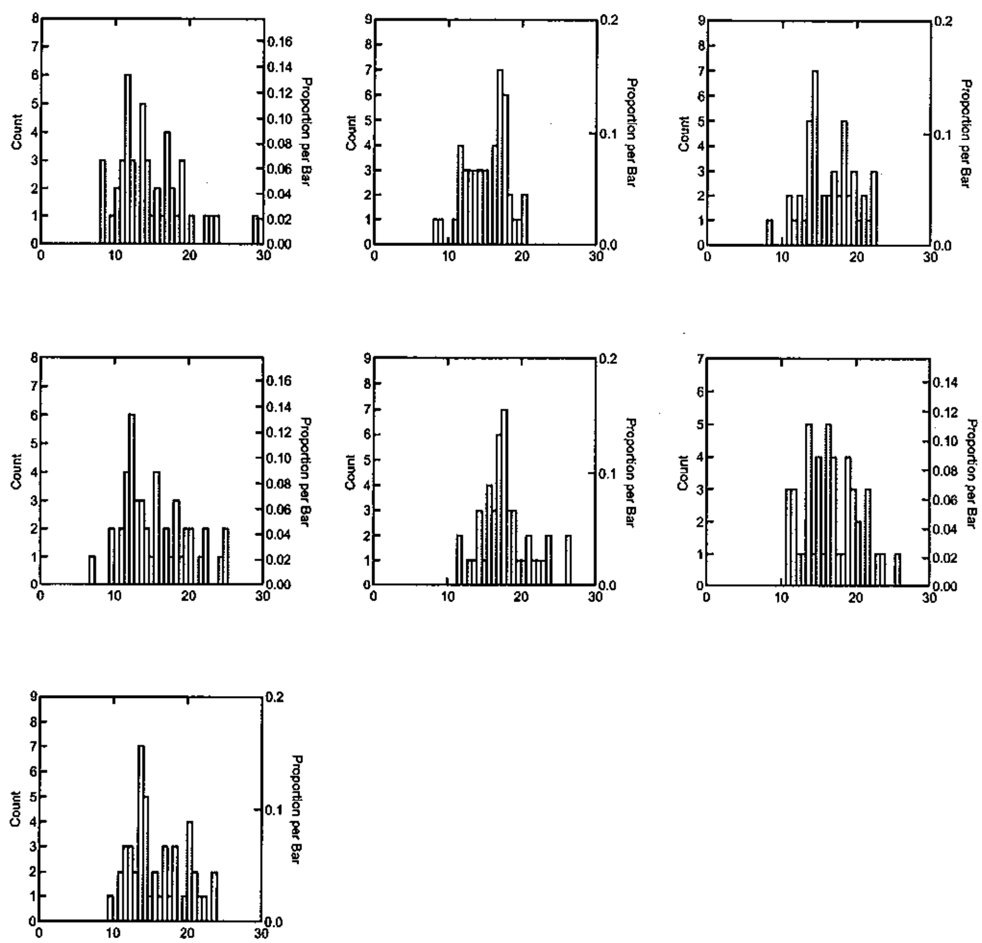


Figure 7. Square root transformed face fly counts (X axis) of grand and great granddams for each counting date.

(Graph order: Left to right, top to bottom: July 14, July 19, July 26, July 30, August 4, August 13, and August 16).

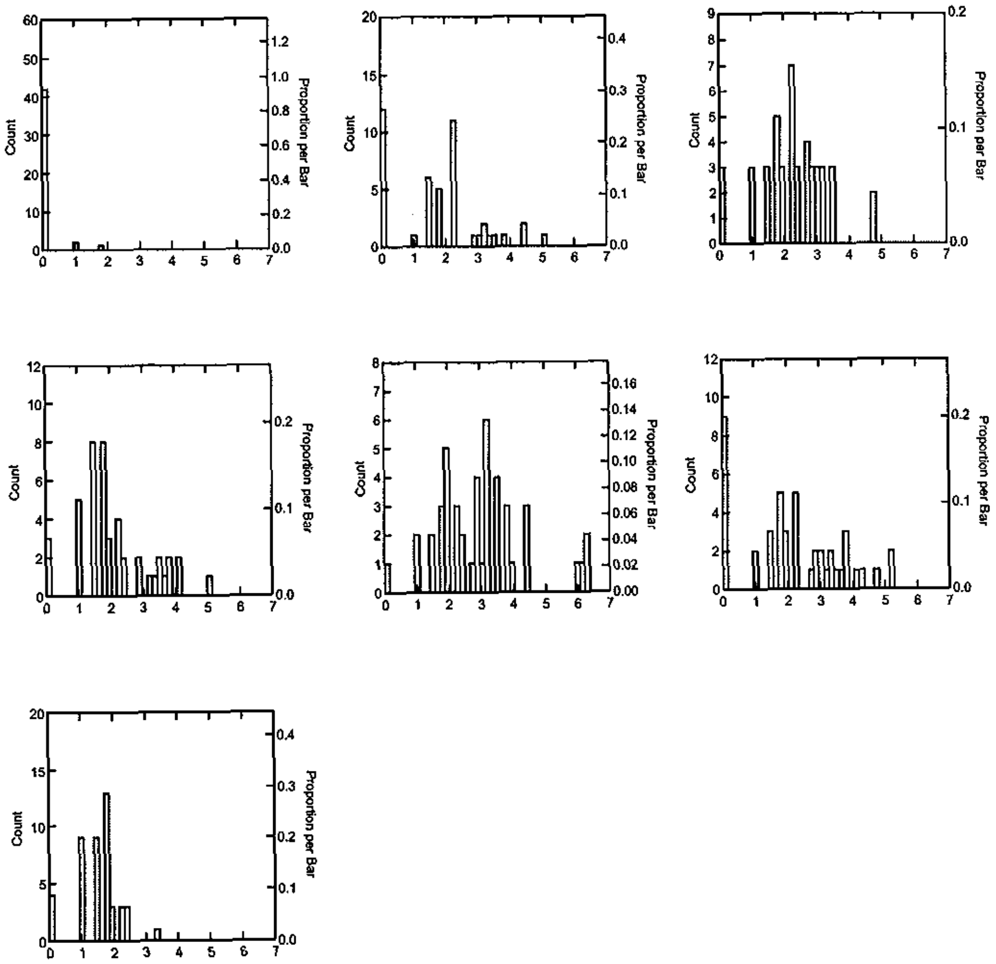


Figure 8. Classification of calves into resistant or susceptible categories based on cluster analysis of transformed whole body horn fly counts (11 counts).

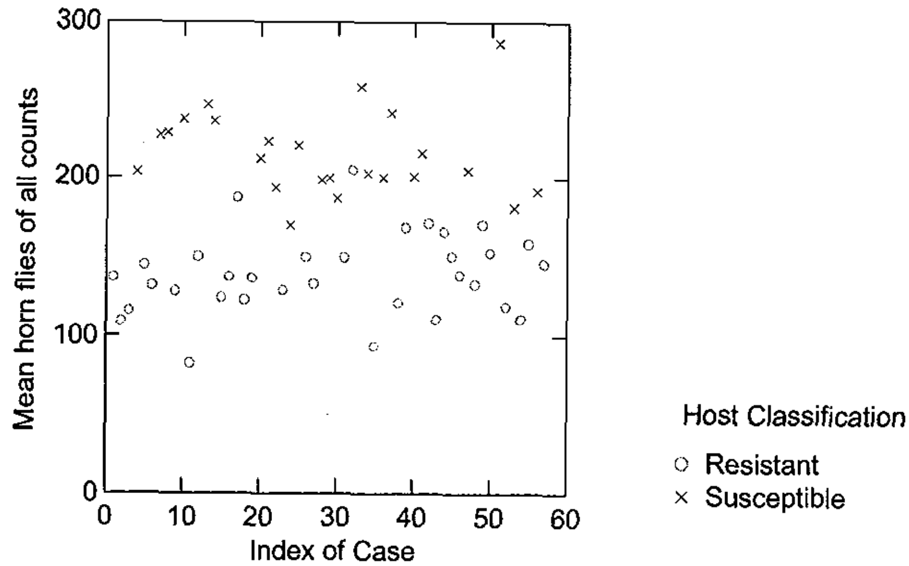


Figure 9. Classification of calves into resistant or susceptible categories based on cluster analysis of mean whole body horn fly counts (11 counts).

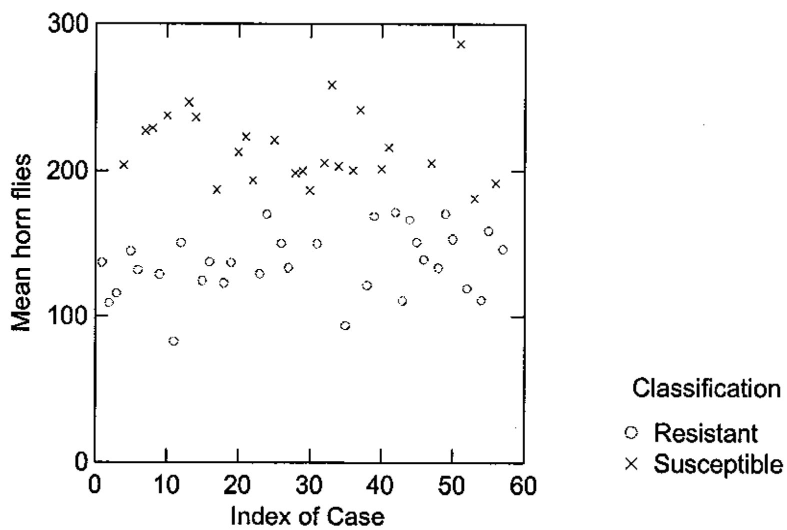


Figure 10. Classification of calves into resistant or susceptible categories based on cluster analysis of square root transformed mean whole body horn fly counts (11 counts).

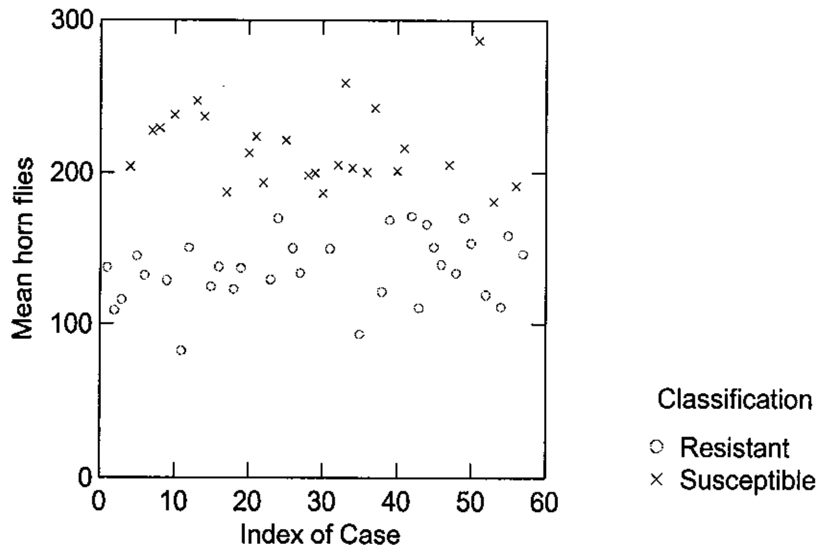


Figure 11. Calf mean horn flies for each counting date for resistant or susceptible groups based on cluster analysis. Susceptible calves had more horn flies (P<.02) for each counting date except July 6.

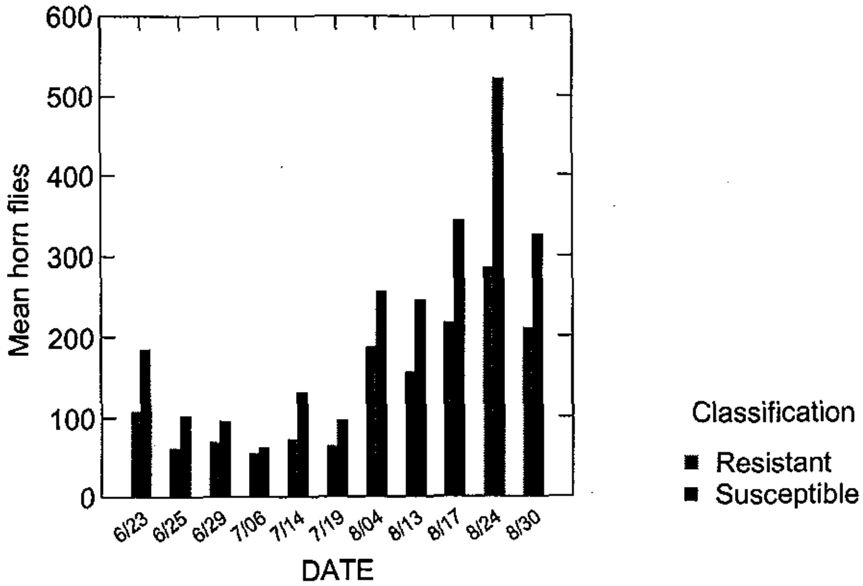


Figure 12. Histogram distribution of calf mean whole body horn fly counts based on cluster analysis using transformed mean horn fly counts into resistant or susceptible host categories.

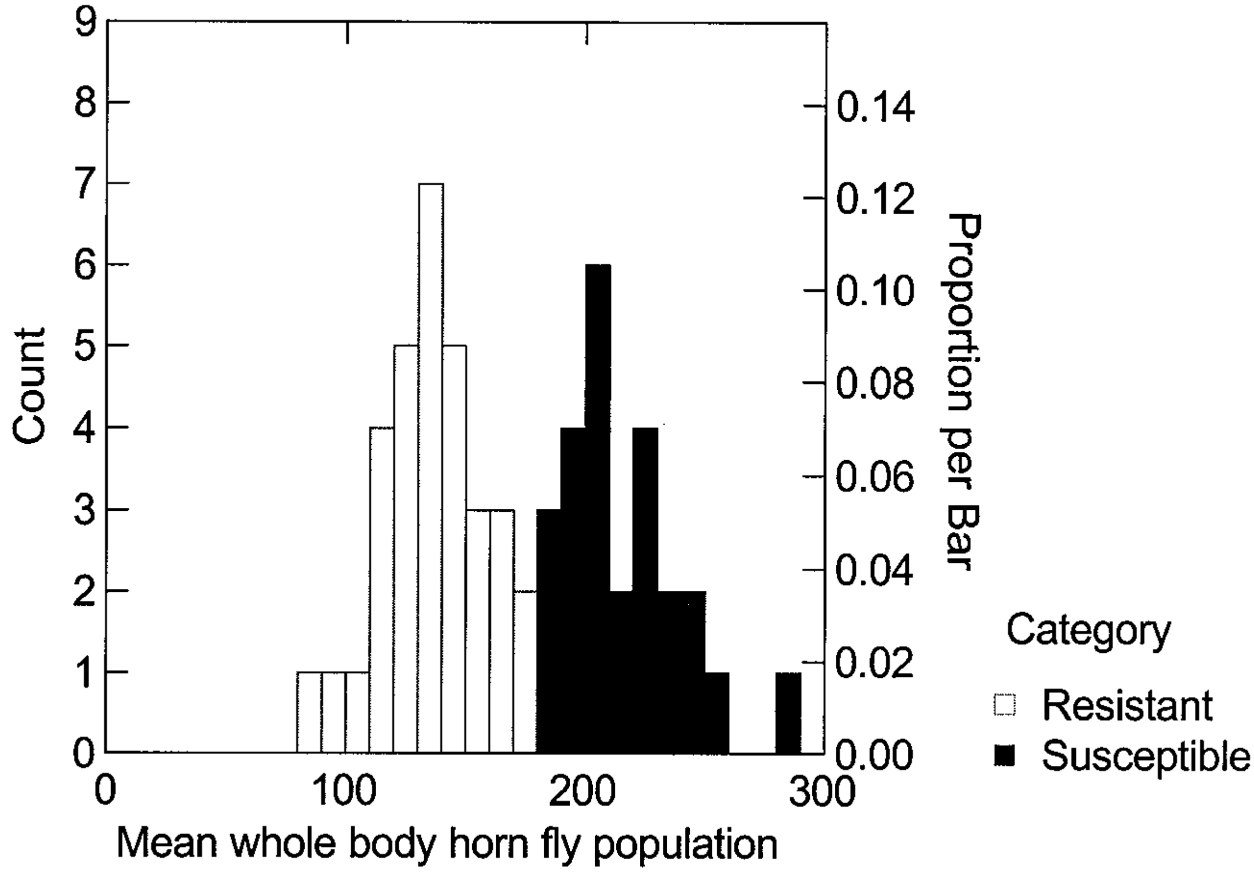


Figure 13. Classification of calves into host resistant or susceptible based on cluster analysis of transformed face fly counts (11 counts).

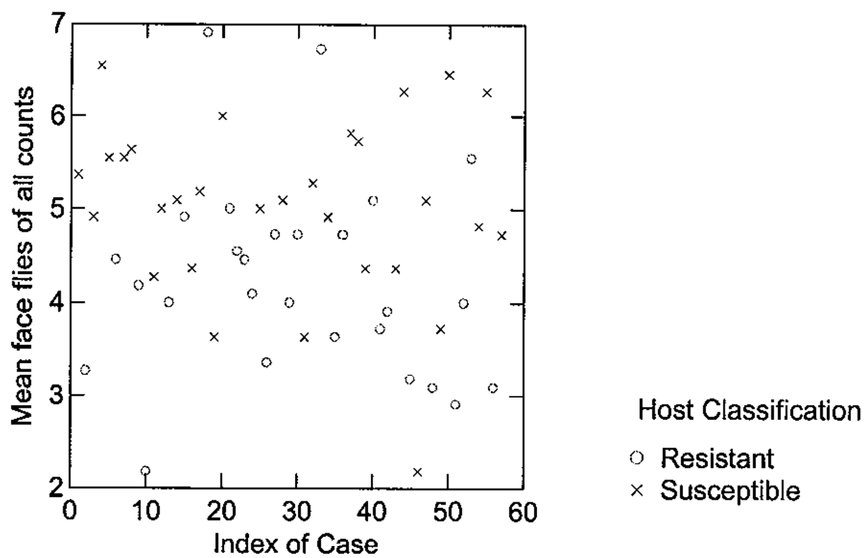


Figure 14. Calves categorized using cluster analysis of a single mean value derived from square root transformed face fly counts.

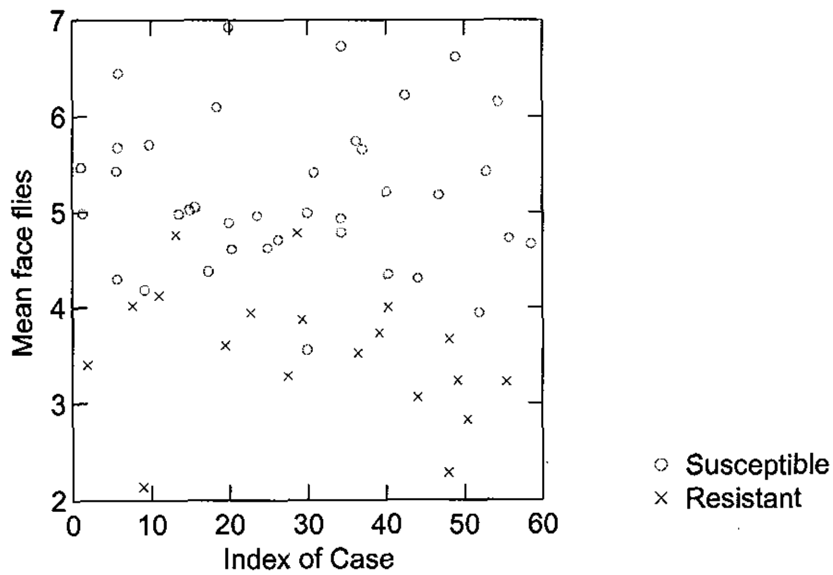


Figure 15. Calves categorized using cluster analysis of a single mean value derived from face fly counts.

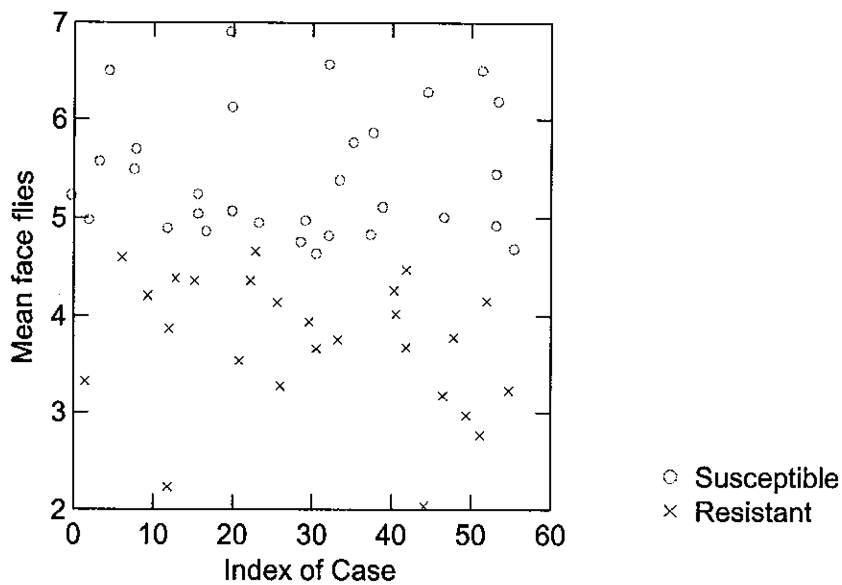


Figure 16. Cow mean horn fly count by host classification based on cluster analysis of horn fly counts taken on individual counting dates.

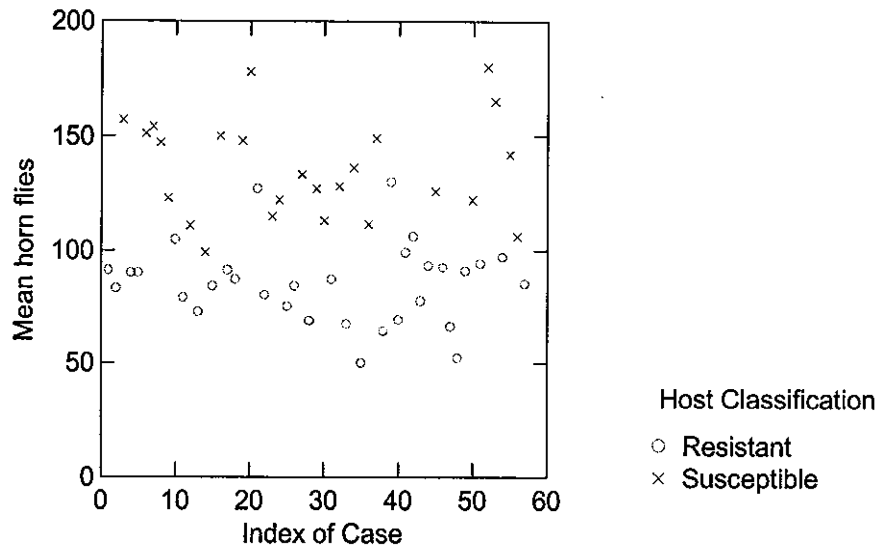


Figure 17. Cow mean horn fly count by host classification based on cluster analysis of square root transformed horn fly counts taken on individual counting dates.

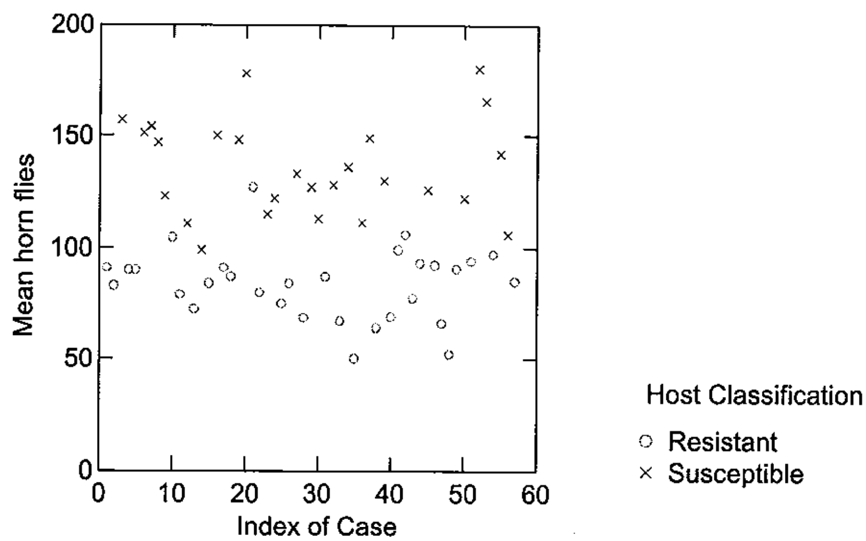


Figure 18. Cow mean horn fly count by host classification based on cluster analysis of mean horn fly counts.

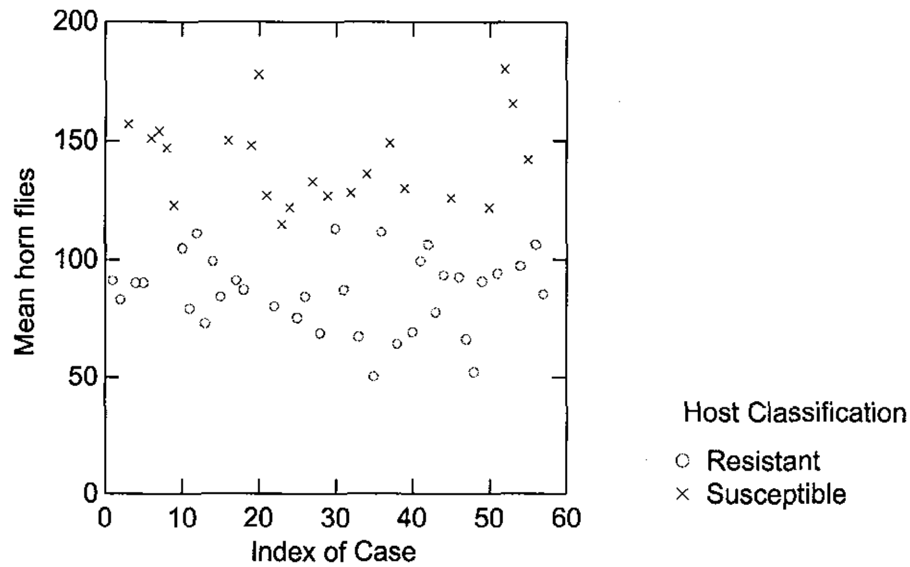


Figure 19. Cow mean horn fly count by host classification based on cluster analysis of square root transformed mean horn fly counts.

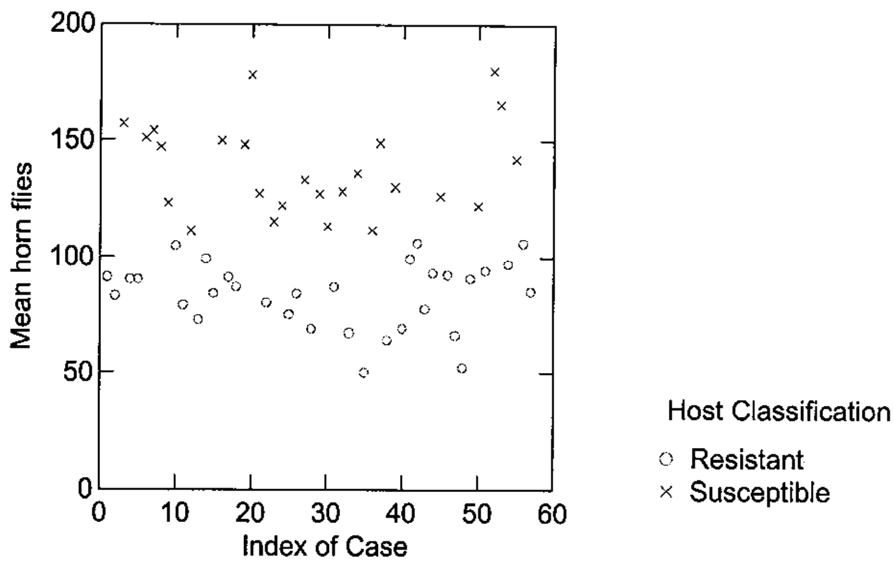


Figure 20. Cow mean face fly count by host classification based on cluster analysis of individual counting dates.

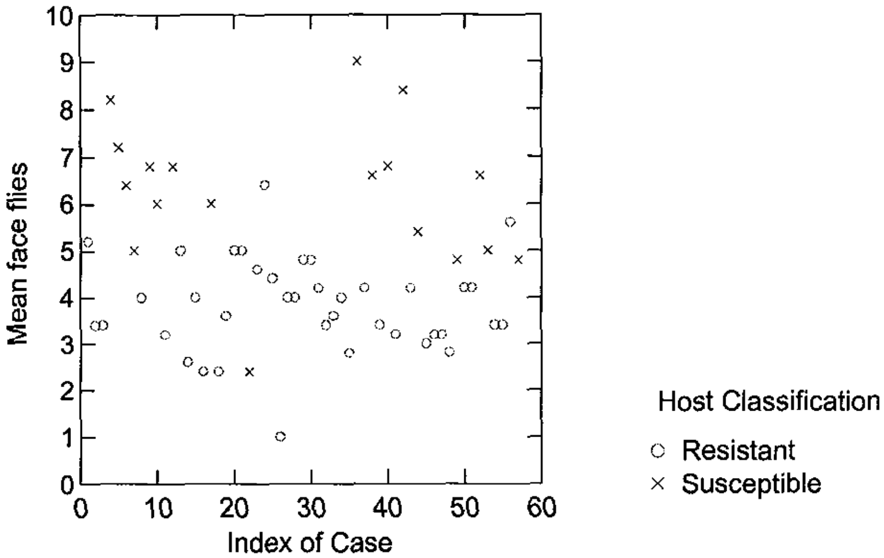


__Figure 21. Cow mean face fly count by host classification based on cluster analysis of individual counting dates with values transformed by square root.__

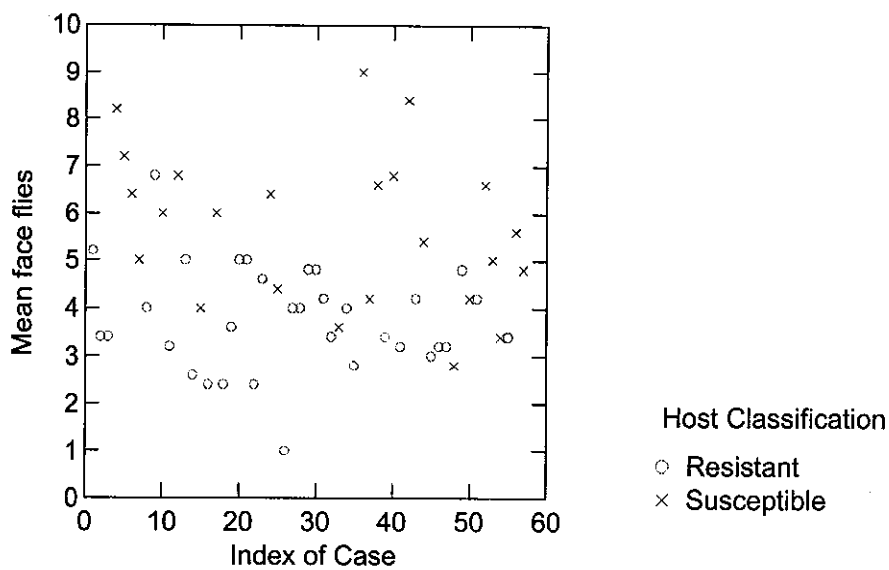


Figure 22. Cow mean face fly count by host classification based on cluster analysis of mean face fly count.

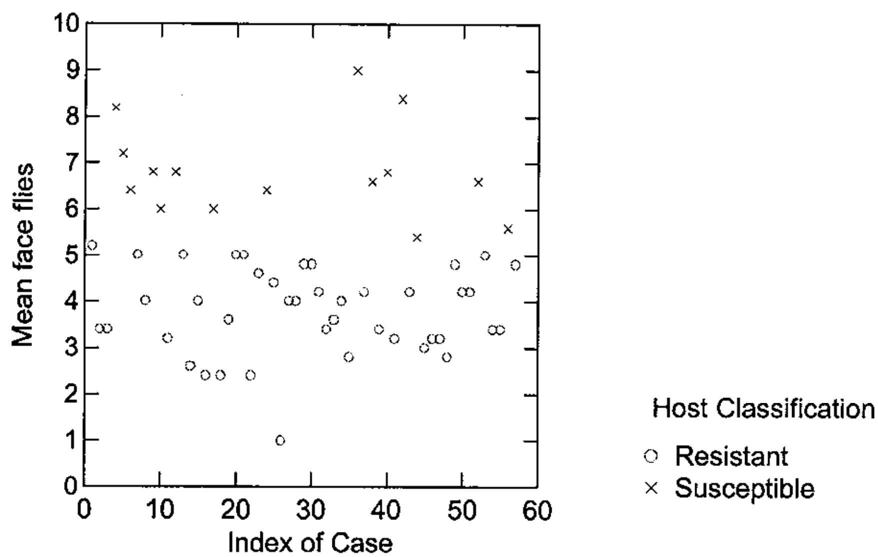


Figure 23. Cow mean face fly count by host classification based on cluster analysis of mean face fly count transformed by square root.

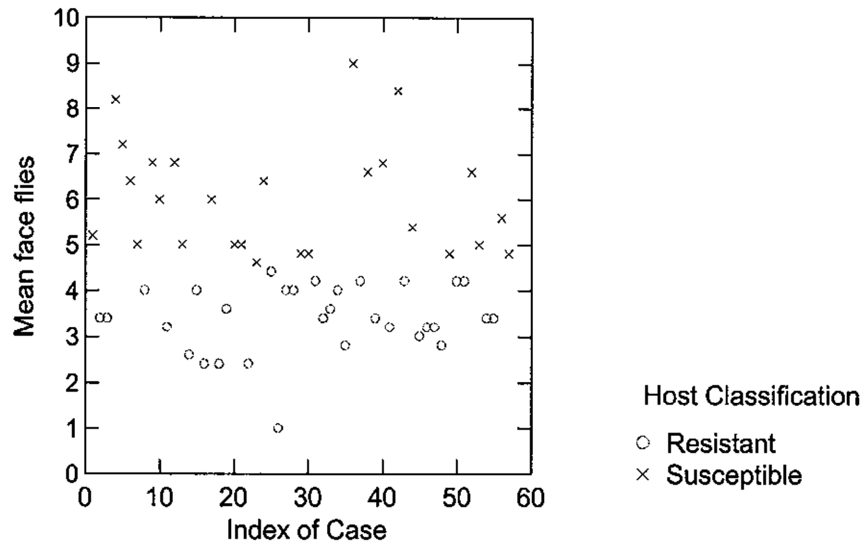


Figure 24. Mean horn flies of grand and great grand dams using individual horn fly counts (n=7).

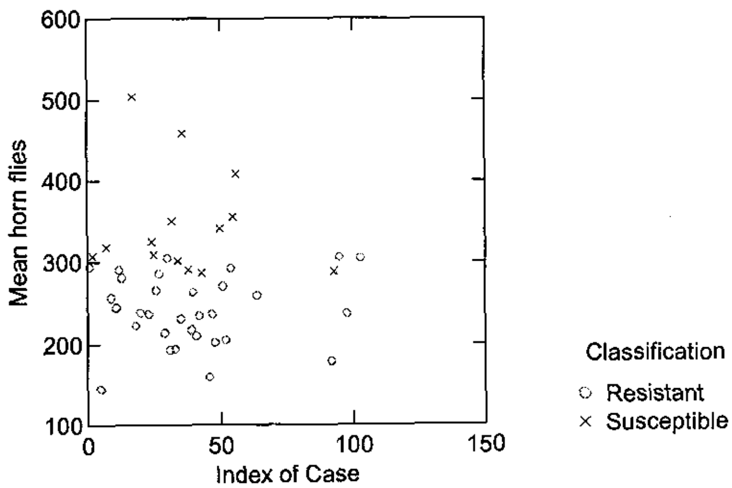


Figure 25. Mean horn flies of grand and great grand dams using square root transformations of individual horn fly counts (n=7).

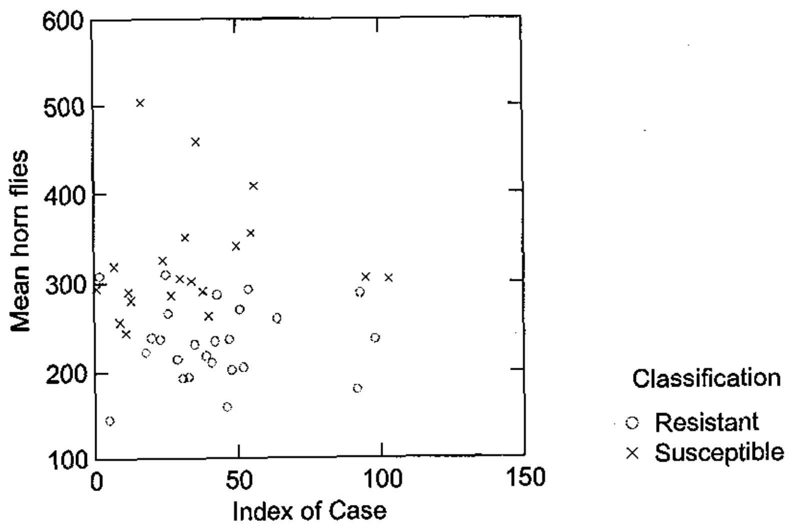


Figure 26. Mean horn flies of grand and great grand dams using mean horn fly count for cluster analysis classification.

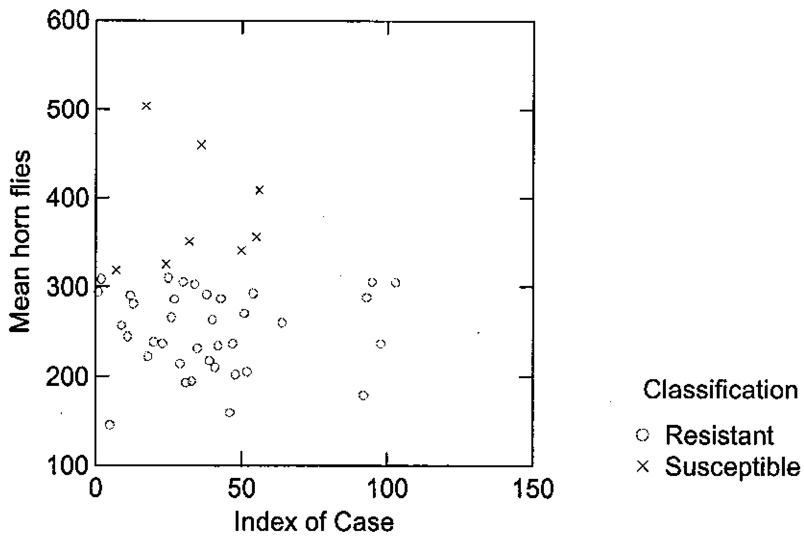


Figure 27. Mean horn flies of grand and great grand dams using square root transformations of mean horn fly count for cluster analysis classification.

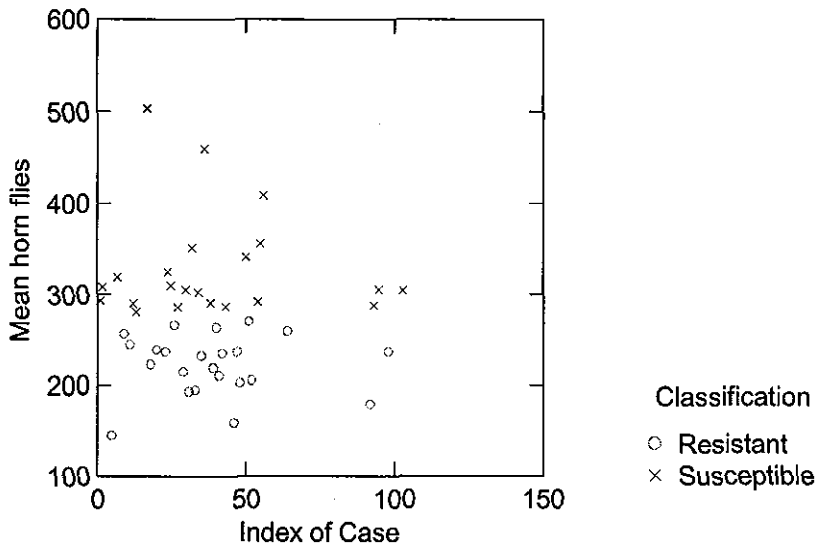


Figure 28. Mean face flies of grand and great grand dams using individual face fly counts (n=7).

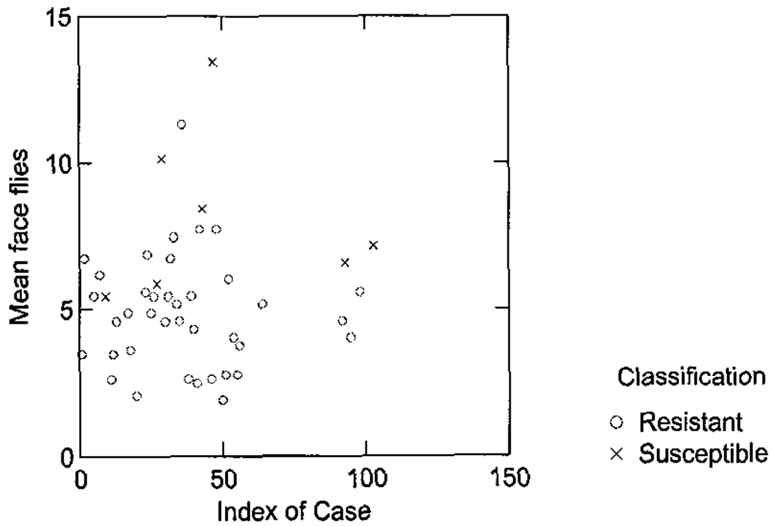


Figure 29. Mean face flies of grand and great grand dams using square root transformations of individual face fly counts (n=7).

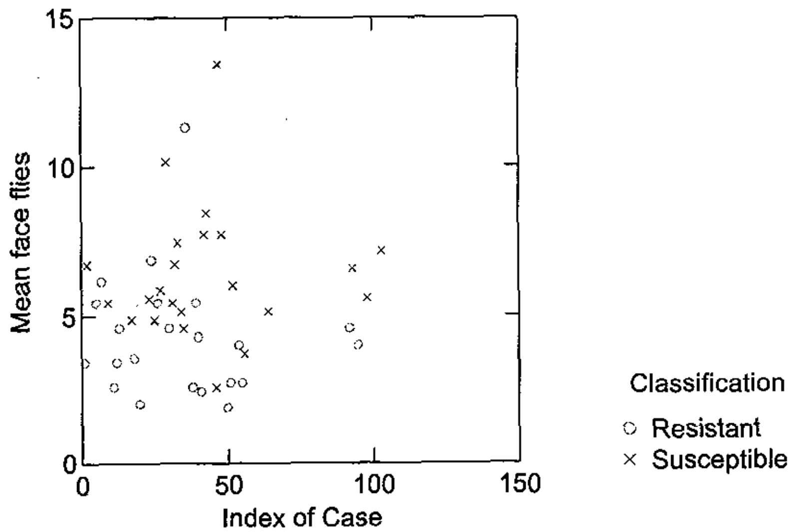


Figure 30. Mean face flies of grand and great grand dams using mean face fly count for cluster analysis classification.

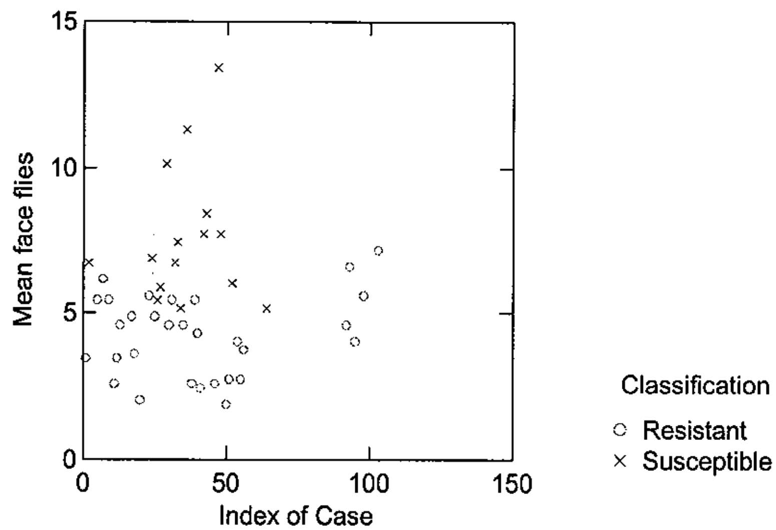


Figure 31. Mean face flies of grand and great grand dams using square root transformations of mean face fly count for cluster analysis classification.

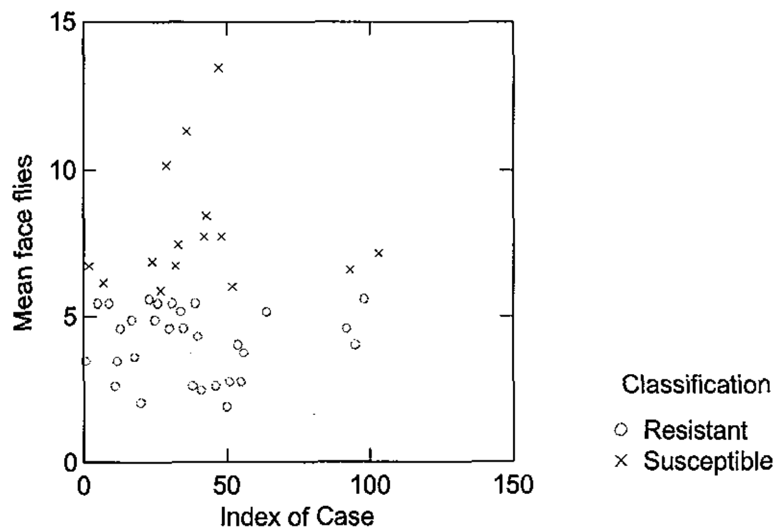
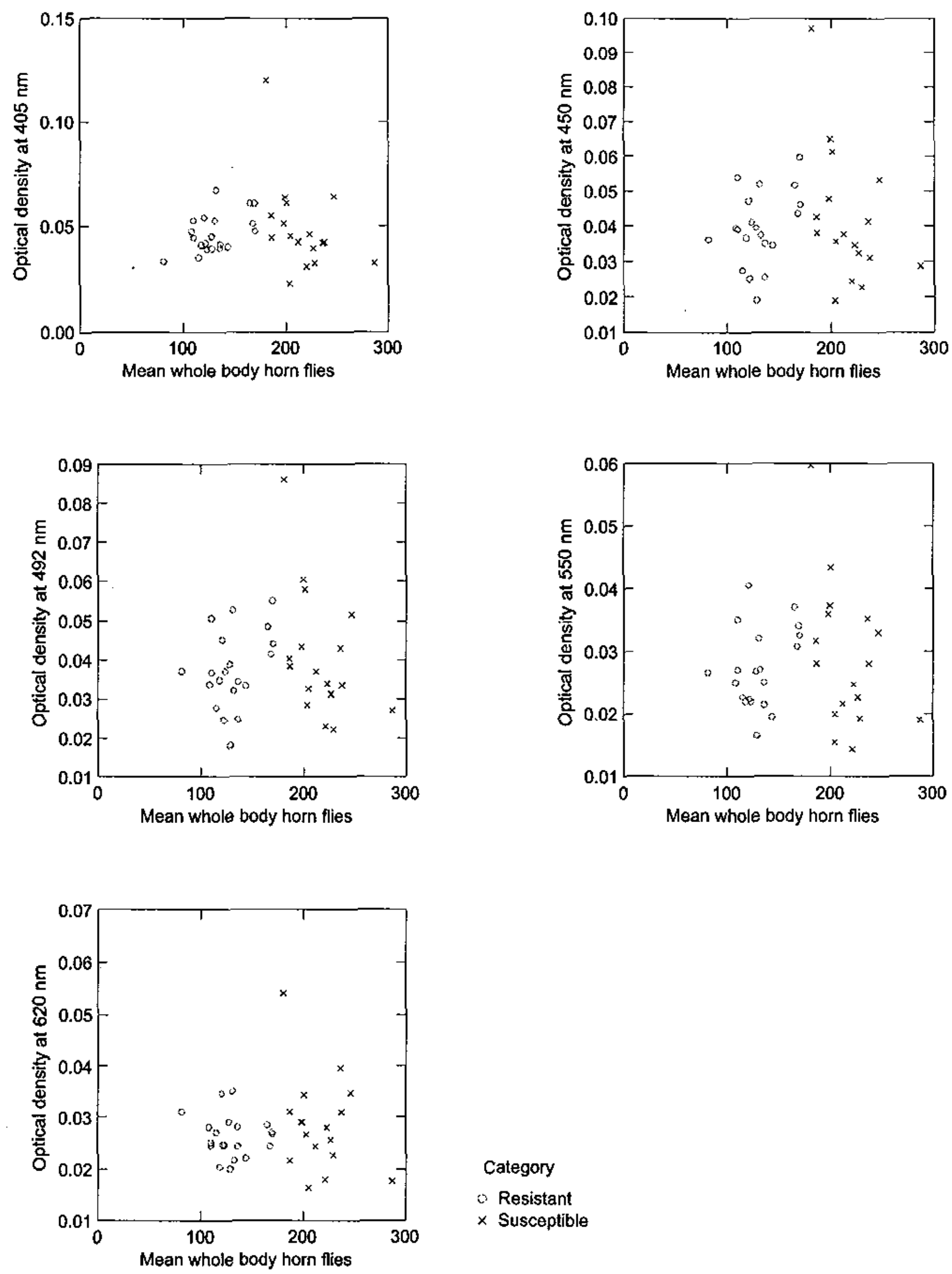


Figure 32. Mean horn flies per head (11 counting dates) plotted with absorbance at five wavelengths. (A405=absorbance at 405 nm, etc.)



Tables

Table 1. Horn flies on calves.

	Number	**Minimum**	**Maximum**	**Mean**	**Stan Dev**
June 23	57	25	590	142	99
June 25	57	20	190	80	43
June 29	57	20	220	82	43
July 6	57	25	140	59	29
July 14	57	8	475	99	90
July 19	57	25	175	79	34
August 4	57	70	505	219	92
August 13	57	50	410	196	93
August 17	57	60	720	274	147
August 24	57	25	920	390	195
August 30	57	70	700	261	119

Table 2. Face flies on calves.

	Number	Minimum	Maximum	Mean	Stan Dev
June 23	57	1	23	8.8	5.8
June 25	57	0	20	5.8	4.4
June 29	57	0	15	4.9	3.6
July 6	57	1	15	4.9	3.0
July 14	57	0	12	2.6	2.0
July 19	57	0	3	0.4	0.8
August 4	57	0	15	3.4	3.3
August 13	57	0	15	5.5	3.6
August 17	57	0	20	5.5	5.0
August 24	57	0	31	5.8	5.4
August 30	57	0	15	3.6	2.9

Table 3. Horn flies on cows.

	Number	Minimum	Maximum	Mean	Stan Dev
June 28	57	30	300	105.2	54.2
July 6	57	27	200	86.5	41.2
July 19	57	40	360	139.8	72.6
July 26	57	22	180	67.1	35.0
August 15	57	45	365	138.2	64.6

Table 4. Face flies on cows.

	Number	Minimum	Maximum	Mean	Stan Dev
June 28	57	2	30	10.9	6.3
July 6	57	0	12	4.5	2.5
July 19	57	0	8	2.7	2.0
July 26	57	0	6	1.3	1.6
August 15	57	0	19	3.5	3.4

Table 5. Summary of horn fly counts for combined grand and great grand dams for each counting date.

	Number	Minimum	Maximum	Mean	Stan Dev
July 14	45	70	855	240	154
July 19	45	70	410	241	85
July 26	45	70	510	282	113
July 30	45	50	635	262	147
August 4	45	130	705	333	129
August 13	45	115	665	290	128
August 16	45	90	555	269	125

Table 6. Summary of face fly counts for combined grand and great grand dams for each counting date.

	Number	Minimum	Maximum	Mean	Stan Dev
July 14	45	0	3	0.1	0.5
July 19	45	0	25	5.0	5.8
July 26	45	0	22	6.2	4.8
July 30	45	0	25	5.6	5.6
August 4	45	0	40	10.9	10.0
August 13	45	0	27	7.0	7.2
August 16	45	0	11	2.7	2.0

Table 7. Comparison of mean, SD, and range for three methods of cluster analysis classification of horn and face flies on calves, cows and grand/great grand dams.

	Mean	SD	Range
Calf Horn Fly			
Resistant Category			
Transformed individual counts, n=33	138.5	25.8	122
Mean, n=32	135.9	22.1	88
Transformed mean, n=32	135.9	22.1	88
Susceptible Category			
Transformed individual counts, n=24	215.3	26.9	117
Mean, n=25	215.6	25.3	105.9
Transformed mean, n=25	215.6	25.4	105.9
Calf Face Fly			
Resistant Category			
Transformed individual counts, n=27	4.239	1.075	4.727
Mean, n=26	3.717	0.656	2.364
Transformed mean, n=19	3.569	0.721	2.727
Susceptible Category			
Transformed individual counts, n=30	5.027	0.953	4.36
Mean, n=31	5.440	0.645	2.182
Transformed mean, n=38	5.196	0.777	3.273
Cow Horn Fly			
Resistant Category			
Transformed individual counts, n=31	83.74	15.89	77.0
Mean, n=35	85.983	15.929	63
Transformed mean, n=32	83.563	14.411	56.0
Susceptible Category			
Transformed individual counts, n=26	135.5	21.48	81.0
Mean, n=22	141.382	18.2	65
Transformed mean, n=25	137.832	19.652	69.0
Cow Face Fly			
Resistant Category			
Transformed individual counts, n=33	3.776	1.099	5.80
Mean, n=42	3.76	0.930	4.2
Transformed mean, n=31	3.394	0.742	3.40
Susceptible Category			
Transformed individual counts, n=24	5.70	1.628	6.20
Mean, n=15	6.813	1.021	3.60
Transformed mean, n=26	6.008	1.231	4.40

Grand & Great Grand Dam Horn Fly			
Resistant Category			
Transformed individual counts, n=25	233.27	43.982	165.0
Mean, n=37	250.069	44.953	165.0
Transformed mean, n=23	222.255	33.408	125.714
Susceptible Category			
Transformed individual counts, n=20	324.143	65.897	259.28
Mean, n=8	382.768	67.718	185.0
Transformed mean, n=22	327.403	58.474	222.857
Grand & Great Grand Dam Face Fly			
Resistant Category			
Transformed individual counts, n=22	4.266	2.079	9.429
Mean, n=30	4.219	1.402	5.286
Transformed mean, n=30	4.081	1.201	3.714
Susceptible Category			
Transformed individual counts, n=23	6.379	2.233	10.857
Mean, n=15	7.60	2.380	8.286
Transformed mean, n=15	7.876	2.150	7.571

Table 8. Calf performance as measured by gain from 1.) February to weaning (June), 2.) weaning to sale (August), 3.) February to August, and 4.) adjusted 205-d weights by fly susceptibility classification of the calf or its dam.

	n	Gain Feb to wean (June)	Gain June to August	Gain Feb to August	Adjusted 205 d wt
Calf Classification					
Resistant	20	206±10.2	66±7.4	272±10.5	324±11.5
Susceptible	17	205±10.8	79±7.9	283±11.1	321±12.2
P value		.94	.26	.47	.89
Dam Classification					
Resistant	23	204±9.2	71±6.8	275±9.5	313±11.6
Susceptible	14	208±11.6	73±8.7	281±12.1	337±12.8
P value		.90	.75	.69	.15

Table 9. Dam classification and numbers of their calves classified resistant or susceptible, Pearson Chi-square .70.

	Calf Classification	
Dam Classification	Resistant	Susceptible
Resistant	13	10
Susceptible	7	7

Table 10. Absorbance (SE) for calves classified as resistant or susceptible to Horn flies.

	Resistant	**Susceptible**	**P**
Optical density			
405 nm	0.048 (0.002)	0.047 (0.003)	.82
450 nm	0.041 (0.002)	0.041 (0.003)	.89
492 nm	0.039 (0.002)	0.040 (0.003)	.81
550 nm	0.028 (0.001)	0.029 (0.002)	.83
620 nm	0.027 (0.001)	0.028 (0.002)	.73